CABLE TESTING

CAPACITANCE UNBALANCE TESTING PROCEDURE
QUADDED OUTSIDE CABLES—VOICE FREQUENCY CIRCUITS

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1. GENERAL

1.01 An important part of the installation of toll and toll entrance cable of the so-called quadded type is electrical tests of various kinds, the purpose of which is to insure that the telephone circuits carried through such cables will meet the high standards of Bell System communication service. One of the most important of these tests, both from the point of view of its effect on service and from the view of the time and man power required for its making, is what is commonly called CAPACITANCE UNBALANCE TESTS. These tests are made at frequent intervals along the cable, require generally a more or less special testing organization and special testing apparatus, and, as explained later, are necessary to prevent crosstalk, that is, the overhearing on one circuit of conversations being carried on over nearby circuits. Among other things, these tests are therefore a safeguard to the secrecy of communication service.

1.02 The purpose of this section is to describe the capacitance unbalance tests that are generally made during the installation of cables and the method of interpreting the test results, and to discuss the manner in which these test results must be taken into account as the installation of the cable progresses. Though quite important to the satisfactory operation of the cable plant, capacitance unbalance tests are not complicated; and while the testing procedure could, to some extent, be presented in a brief step-by-step manner, it seems better to present the steps in a form of discussion with illustrations, so as to establish a better general understanding of the work, and to facilitate the use of judgment when this is required. To this end also, and prior to discussion of the procedure, a description is given of the cable itself and of the ways in which overhearing of conversations may occur.

2. DESCRIPTION OF QUADDED CABLE

2.01 It is helpful on taking up cable capacitance unbalance work to consider first the actual construction of quadded cables, particularly those features that are intimately associated with the crosstalk problem. The significance of the term QUADDED is that the conductors contained in a cable so designated are grouped into units called quads, where a quad consists of two twisted pairs of wires twisted together. The wires are individually insulated with a paper wrapping. The length of twist of the two wires of a pair is in the order of two to three feet and to help hold the two wires together, a cotton "binding" string is wound around them. The two pairs forming a quad are twisted together, a complete twist occurring every five to twelve inches. With this length of twist no binding string is required around the two pairs to hold them together.

2.02 Each quad provides for three talking paths or circuits, one over each of the two pairs or side circuits, and a third over the so-called phantom circuit. A description of these three circuits of a quad is given later (Part 3).

2.03 The various quads contained within the lead sheath of a cable may be laid up in a number of ways to form the core of the cable, but in general, a center is formed from one or three quads, and in some instances pairs, and around this center the remaining quads are laid up in successive layers. There may be as many as six or seven layers of quads in a cable. The quads in a layer are not run straight through the cable sheath, that is, parallel to the sheath, but are twisted or "stranded" around the layers beneath so as to make the core into a more compact form. Two adjacent layers are stranded in opposite directions around the layers beneath.

Description of Quadded Cable

2.04 To help prevent crosstalk between the three circuits of a quad, as discussed in detail later, these circuits are "transposed" against one another by giving a different length of twist to each of the pairs and by twisting the two pairs, to form the phantom, with a still different length of twist. Crosstalk between the circuits of this quad and those of adjacent quads in the same layer is similarly limited by forming the adjacent quads with other pair and phantom twists. In addition to these two types of quads as regards length of twists, one of a third type is placed in each layer, the chief purpose of which is to prevent the adjacency of similarly twisted quads as would necessarily occur in layers containing an odd number of quads if only two types were used. The third type of quad also provides a means of identifying the relative position of the various quads in a layer and it is for this reason that a quad of this type is placed also in those layers containing an even number of quads. Identification of these three types is made by a distinctive color of the paper insulation. The two wires of a pair have the same color of insulation. The three types with their color markings are given in the table below.

Colors of Insulation

Type	Pair 1	Pair 2
1	White	Blue
2	Green	Red
3	Orange	Red
Tracer	White	Orange

Note: One tracer quad is generally placed in each cable, primarily for substitution for a regular quad on which trouble may exist and cannot be conveniently cleared.

2.05 In capacitance unbalance testing work, Pair 1 is commonly referred to as the white side of a quad and Pair 2 as the black side; these are the designations employed on the capacitance unbalance test set. This designation of the pairs is purely arbitrary and for all practical purposes, the blue and the red pairs could be considered Pairs 1 if desired, it being necessary merely to follow consistently a certain method of reference.

2.06 Crosstalk between circuits in different layers is to a large extent prevented by stranding adjacent layers in opposite directions and also by applying to the three types of quads in one layer, lengths of twist different from those of the three types in the adjacent layers. The three types in one layer though having lengths of twists different from the three types of adjacent layers have the same color designations and for the purpose of this section may be referred to by the same type numbers.

2.07 In addition to the classification by insulation color types, the quads in a toll cable are classified without regard to these types into groups for two-wire and four-wire operation, and the two-wire group in some cases subdivided into others depending on the gauge of wire or on the type of loading associated with the circuits. In earlier cables these various groups were identified by the color of binding strings, so that for example, the two groups of four-wire circuits (one group for the transmission of speech in one direction, and the second group for transmission in the opposite direction) were commonly referred to as the "red" and "green" groups. All quads in the red group had red binding strings. A "universal" color code has now been adopted for the binding strings, so as to facilitate using the same cable design for more than one job, and also to make easier the identification of quads. Under this scheme the segregated groups are determined by means of the quad numbers, there being no distinction between groups as regards the color of binding strings. Orange, blue, white, and black binding strings are used, and these, along with quad types, numbers, and other features, are indicated in Figure 1, which illustrates a standard cable drawing, covering a cable which contains 19 quads of 16 gauge, 114 quads of 19 gauge, and 6 pairs of 16 gauge conductors (and the usual tracer quad). The 16 gauge pairs are used for the transmission of programs to be broadcast for radio reception.

Description of Quadded Cable

AT&T Co.
DEPT. OF
DEV. AND RES.

Lead Covered Paper Insulated Quadded Cable

Drawing No. CA-3

- RATING -
AT&T CO. STANDARD

ENGINEER LCS
APPROVED ALR GSC
DATE 6-11-29

Make-Up

19 QUADS 16 AW GAUGE
6 PAIRS 16 AW GAUGE
114 QUADS 19 AW GAUGE
1 QUAD 22 AW GAUGE

Arrangement of Core

CENTER 1 QD. 16 GA.	1ST LAYER 6 QDS. 16 GA.	2ND LAYER 12 QDS. 16 GA.	3RD LAYER 22 QDS. 19 GA.	4TH LAYER 24 QDS. 19 GA. 3 PRS. 16 GA.	5TH LAYER 30 QDS. 19 GA. 3 PRS. 16 GA.	6TH LAYER 38 QDS. 19 GA. 1 QD. 22 GA.
2 W 139	3 O 133	3 O 121	3 O 99	3 O 72	3 O 39	3 O 1
	1 B 134	1 B 122	1 B 100	1 B 73	1 B 40	1 B 2
	2 W 135	2 W 123	2 W 101	2 W 74	2 W 41	2 W 3
	1 W 136	1 W 124	1 W 102	1 W 75	1 W 42	1 W 4
	2 K 137	2 K 125	2 K 103	2 K 76	2 K 43	2 K 5
	1 W 138	1 W 126	1 W 104	X 77	X 44	W TRACER
		2 W 127	2 W 105	1 W 78	1 W 45	1 W 6
		1 W 128	1 W 106	2 W 79	2 W 46	2 W 7
		2 W 129	2 W 107	X 80	X 47	1 W 8
		1 K 130	1 K 108	1 W 81	1 W 48	2 W 9
		2 W 131	2 W 109	2 W 82	2 W 49	1 K 10
		1 W 132	1 W 110	X 83	X 50	2 W 11
			2 W 111	1 K 84	1 K 51	1 W 12
			1 W 112	2 W 85	2 W 52	2 W 13
			2 K 113	1 W 86	1 W 53	1 W 14
			1 W 114	2 W 87	2 W 54	2 K 15
			2 W 115	1 W 88	1 W 55	1 W 16
			1 W 116	2 K 89	2 K 56	2 W 17
			2 W 117	1 W 90	1 W 57	1 W 18
			1 K 118	2 W 91	2 W 58	2 W 19
			2 W 119	1 W 92	1 W 59	1 K 20
			1 W 120	2 W 93	2 W 60	2 W 21
				1 K 94	1 K 61	1 W 22
				2 W 95	2 W 62	2 W 23
				1 W 96	1 W 63	1 W 24
				2 W 97	2 W 64	2 K 25
				1 W 98	1 W 65	1 W 26
					2 K 66	2 W 27
					1 W 67	1 W 28
					2 W 68	2 W 29
					1 W 69	1 K 30
					2 W 70	2 W 31
					1 K 71	1 W 32
						2 W 33
						1 W 34
						2 K 35
						1 W 36
						2 W 37
						1 W 38

Average Capacitance, Microfarad per Mile

	DESIRED	MAX.
16-GA. QUADS		
SIDE CIRCUITS	0.062	0.068
PHANTOM CIRCUITS	0.102	0.112
19-GA. QUADS		
SIDE CIRCUITS	0.062	0.068
PHANTOM CIRCUITS	0.102	0.112
22-GA. QUAD		
SIDE CIRCUITS		0.078
PHANTOM CIRCUIT		0.128
16-GA. PAIRS	0.062	0.068

SHEATH THICKNESS - 0.125 INCH.
OUTSIDE DIAM. - APPROX. 2.6 INCHES.
WEIGHT - APPROX. 7.6 LBS. PER FT.

EACH QUAD IS REPRESENTED BY A SQUARE, THE RELATIVE SIZE OF THE SQUARE INDICATING THE GAUGE.

NUMERALS AT LEFT OF SQUARES INDICATE TYPES OF QUAD, VIZ.

COLORS OF INSULATION

TYPE	PAIR 1	PAIR 2
1	WHITE	BLUE
2	GREEN	RED
3	ORANGE	RED
TRACER	WHITE	ORANGE

LETTERS INDICATE COLORS OF BINDING STRINGS ON PAIRS, VIZ.

B - BLUE
K - BLACK
O - ORANGE
W - WHITE

NUMERALS AT RIGHT OF SQUARES INDICATE THEORETICAL COUNT.
EACH NON-QUADDED PAIR IS REPRESENTED BY X.
ALL NON-QUADDED PAIRS HAVE WHITE INSULATION.

SUPERSEDES AT&T SPEC. 4573
" " " 4680
" " " 4744
" " " 4918

Fig. 1.

2.08 The above description, while to a large extent applicable to quadded cable generally, applies more specifically to toll cable. In toll entrance and intermediate cables, which form links in open wire circuits, the classification of groups will generally be by the gauge of wire, but where carrier current systems are to be operated through a cable, an additional group, or additional groups, will be formed by the quads needed for these systems. In many of the toll entrance and intermediate cables, for carrier system operation purposes that need not be discussed here, three types of quads are alternated in a layer rather than two, as is the case with toll cable. Also, a large number of non-quadded pairs may be found in these cables, in some cases provided for carrier circuits and in other cases for local telephone circuits.

2.09 It is important to note that the quads contained in toll, toll entrance and intermediate cables are divided into certain segregated groups according to the type of facility to be provided, the gauge of wire, or the system of loading; and that as the identity of the various groups is usually maintained throughout the cable, each group must be treated independently of the others in capacitance unbalance testing work. The types of quads need not in general be considered in the testing.

3. DESCRIPTION OF SIDE AND PHANTOM CIRCUITS

3.01 The foregoing has described the telephone plant with which capacitance unbalance testing is concerned. Before details of capacitance unbalance testing are taken up and in order better to convey the purpose of the work, it is desirable to consider briefly the way crosstalk may occur between two telephone circuits.

Description of Side and Phantom Circuits

3.02 As already seen, we are, in quadded cable, dealing with quads, a quad comprising four wires over which three talking circuits are established. Figure 2 shows the four wires (W, WM, B, and BM indicating respectively the white, white mate, black, and black mate wires) of a quad arranged to provide for these three circuits.

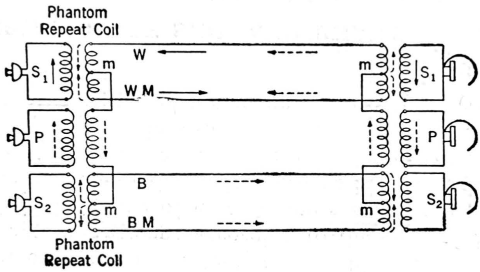


Fig. 2.

3.03 A type of transformer which in telephone work is called a phantom repeating coil, is shown connected to each end of pairs W-WM and B-BM, with one winding connected to a transmitter at one end and to a receiver at the other end. Considering the circuit established over wires W and WM, which is designated S_1 (side circuit 1), a person talking into the transmitter sets up an electrical current which flows through the coil winding to which the transmitter is connected. As its name implies, the coil repeats or induces the current into the other winding, from which the current at a given moment will pass out to the distant end of the circuit, over wire WM for example, through the winding at that end, and back to the talking station over wire W. The path of this current is shown by solid arrows. Speech currents are alternating in character, that is, they will flow in one direction at a given instant and in the opposite direction the next, so that at times, the direction of flow will be opposite to that shown. At the distant end, this current is repeated into the winding connected to the receiver and will then pass through the receiver and reproduce the original speech.

3.04 It will be noted from Figure 2 that the midpoints (m) of the windings connected to pairs W-WM and B-BM are brought out and connected to another repeating coil, forming what is called a phantom circuit (designated P on the figure). Instead of going out over one wire and returning by another, as is the side circuit case, the phantom circuit current goes out over the two wires of one pair in parallel (that is, half in one wire and half in the other) and returns in similar manner over the two wires of the other pair. This current in leaving the coil goes up to the midpoint (m) of the coil connected to one side circuit (in this case B and BM as indicated by the dashed arrows). From point m, there are two equally easy ways for the current to get out on the wires of the quad so that it naturally divides equally between them. These two equal currents as indicated by the dashed arrows, pass out over the quad wires, come together again at point m of the repeating coil at the distant end, and from there pass through the repeating coil on the phantom circuit and return to the starting point by way of wires W and WM. The original speech will be reproduced in the receiver connected to the phantom circuit in the same manner previously described for the side circuit. This speech, however, will not be heard on the side circuits, for as seen, the current divides into two equal parts, and these flow in opposite directions through the two halves of a repeating coil connected to a side circuit. The current thus induced into the drop or receiver side of the coil by one-half line winding is in opposite direction to and cancelled by that induced by the other half line winding.

3.05 To prevent electrical speech currents on one circuit from being heard on another, that is, to prevent crosstalk, the points m must be at the exact center of the repeating coils, and precautions must be taken to prevent the currents from passing from one circuit to another after they get out on the quad wires. The first matter involves the "balance" of repeating coils, and is an equipment question with which we are not concerned here; the second involves characteristics of the cable plant and, therefore, is the problem at hand.

4. CROSSTALK PRODUCTION

Crosstalk Caused by Currents

4.01 The current, after getting out on the wires of the quad, may be partially transferred to another circuit in several ways, some of which we need not treat here. One way is by what is commonly called magnetic induction. A current flowing through a conductor causes magnetic lines of force to be set up around the conductor and these lines, if they encircle another conductor, set up or induce a current into that conductor. For this action to take place the lines of force must be in motion, either building up or collapsing, or in other words the inducing current must be alternating in character, such as voice currents are. The principle of magnetic induction is simply that of a transformer or repeating coil. The strength of the magnetic field or the number of lines of force that pass through a given space (for example, the space occupied by a conductor) becomes smaller with increased separation from the conductor that carries the inducing current. (The conductors that carry the inducing current are generally called the DISTURBING CIRCUIT; the conductors into which current is induced are the DISTURBED CIRCUIT.)

4.02 If the two conductors of a pair are encircled, a current is induced in each, and if the two wires of this pair are separated, naturally more lines encircle the one nearer to the wire carrying the inducing current. This action is shown to an exaggerated degree in Figure 3, which illustrates a pair of wires W and WM carrying current and wires B and BM being encircled by the lines of force.

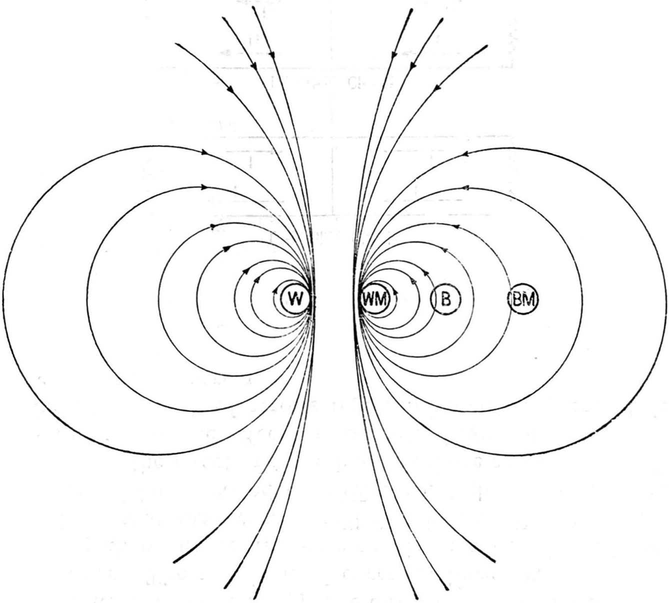


Fig. 3.

Crosstalk Production

4.03 The current in wire W is in the opposite direction to that in wire WM, so that the two currents induced by these in wire B will be in opposite directions, and tend to cancel each other. The two induced currents, however, are not exactly equal, owing to the greater distance of wire W from wire B, so that some current will flow in wire B. In Figure 3 the lines of force around wire W are not shown as encircling wire B, but the effect of these lines on those around wire WM acts to produce the effects mentioned. Figure 4 shows these actions, the length of arrows representing in exaggerated degree the size of currents.

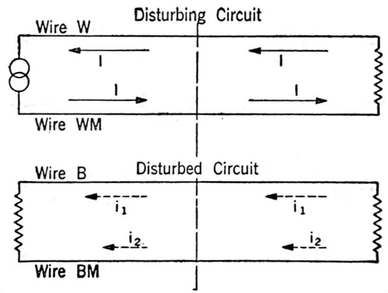


Fig. 4.

4.04 This figure represents a small length of a quad, divided into equal portions by the vertical dashed line. The inducing current, I, induces in each half of wire B the equal currents i_1 and i_1, and in wire BM, the equal currents i_2 and i_2.

Both of the i_1's are flowing in the same direction so the resultant current is 2 i_1; both of the i_2's are flowing in the same direction also, so that the current in wire BM is 2 i_2. The current 2 i_1 is opposed at the end of the circuit by current 2 i_2, and the difference between these is the current that will flow around the circuit and be heard by a person on that circuit. This difference is appreciable, since i_2 is less than i_1, owing to greater distance of wire WM from the disturbing conductors, and hence to the fewer encircling lines of force.

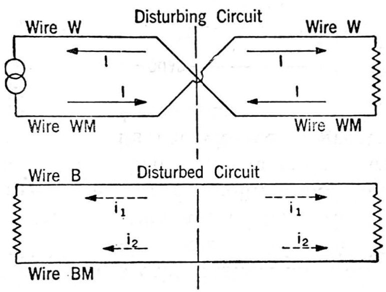


Fig. 5.

4.05 Suppose now wires W and WM were reversed or transposed at the center of the quad as shown in Figure 5. The two i_1's will now be opposite in direction since, due to the transposition, the inducing current I in the wire adjacent to wire B is in one direction for half the length and in the opposite direction for the other half. Similarly, the i_2's are opposite so that the resultant current is evidently zero ($i_1 - i_1 + i_2 - i_2$). The wires of both circuits are twisted so that transpositions are made in the disturbed circuit as well as in the disturbing circuit. As before noted the number of twists for a given length is different for the two circuits. This prevents the frequent occurrence of transpositions in both circuits at the same point, which is necessary since a transposition in one circuit would cancel the effect of a transposition in the other circuit if the two were made at the same point. The method of twisting the conductors together with other factors reduces the magnetic induction, so far as we are concerned here, to such a small value that we do not have to consider this type of induction during the installation of quadded cable.

Crosstalk Caused by Voltages

4.06 Electric induction is another process by which crosstalk may be produced and it is this that we are primarily interested in as regards cable installation work. Two metallic elements such as two wires of a cable, separated by paper and air as in a cable, constitute a condenser, through which, as is known, a current will flow if a voltage like that produced in a circuit by speech is applied to the metallic elements. The size of this condenser or its capacitance is greater with smaller separations between the elements.

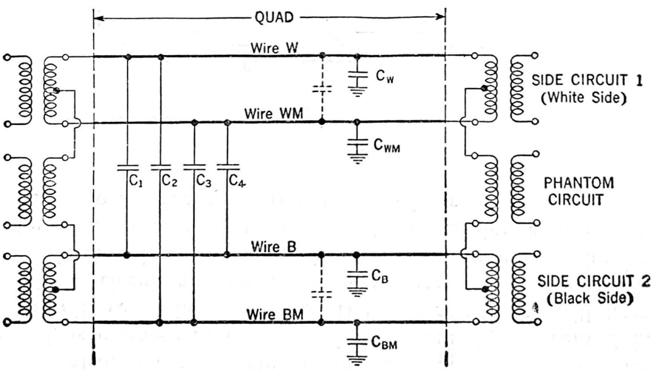


Fig. 6.

4.07 The four wires of a quad therefore constitute a network of condensers as shown by Figure 6, there being capacitances between wires such as C_1, C_2, C_3, and C_4, and also capacitances between the wires and the cable sheath or ground, such as C_W, C_{WM}, C_B, and C_{BM}. (For completeness two other condensers are shown, in dotted lines, one between wires W and WM, and the other between wires B and BM. These condensers add to the so-called mutual capacitance of the circuits. They are not directly concerned in the unbalance work of this section and will not be considered further in the section.) If equalities existed among these capacitances, that is, if C_1 C_2, C_3, and C_4 were all equal and C_W, C_{WM}, C_B and C_{BM} were all equal, current transferred through one capacitance would be canceled by an equal but opposite current through another, so that the resultant current to flow around the disturbed circuit would be zero. Actually, such equalities are not obtained, and the condition resulting, an inequality of capacitances or CAPACITANCE UNBALANCE, can be illustrated as in Figure 7.

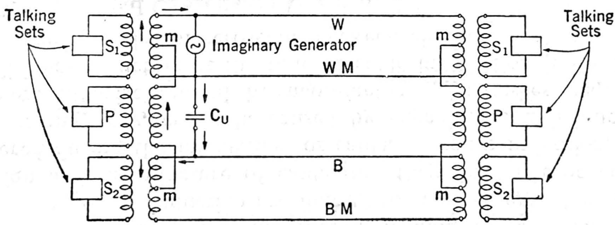


Fig. 7.

4.08 The small condenser, C_u, represents the unbalance and the element labeled "Imaginary Generator" represents the voltage impressed on circuit W-WM by the person talking on that circuit. As can be seen and as indicated by the arrows, this generator will cause a current to flow through C_U, through the repeating coil on the side circuit B-BM, through the repeating coil of the phantom circuit, through the repeating coil on side circuit W-WM, and back to the generator. The current in thus passing through the coils will be repeated into the other windings, so that persons on the phantom circuit and side circuit B-BM will hear the conversation being carried on over circuit W-WM. It is for the reduction of such unbalances as this that capacitance unbalance test splicing of cable is done.

5. CABLE CAPACITANCE UNBALANCES

5.01 As noted before, the factors leading to crosstalk by magnetic induction are limited to such an extent in the design and manufacture of cable that they need not be considered during the installation of cable. Electric induction, or as we may say, crosstalk caused by capacitance unbalances, though likewise limited by manufacturing processes require additional reduction at the time of cable installation if we are to prevent intolerable crosstalk between circuits.

Quad-to-Quad Capacitance Unbalances

5.02 Capacitance unbalances exist between any two circuits in a cable, and, when the two circuits involved are in different quads, the unbalances are called quad-to-quad (or inter-quad) unbalances. Since two quads are generally separated from each other to an appreciable extent, quad-to-quad unbalances are relatively small and except in special cases are not a consideration in cable installation work. It is these unbalances, however, that require the quads to be separated into circuit groups as mentioned in paragraph 2.07.

Within-Quad Capacitance Unbalances

5.03 Since the capacitance between two wires increases with smaller separation between the wires and since the four wires of a quad are twisted very close together, the largest capacitances, and likewise capacitance unbalances, are those involved in individual quads. Unbalances of this kind may be called within-quad (intra-quad) capacitance unbalances, that is, capacitance unbalances between two circuits in the same quad. These are the unbalances we are interested in, and are the ones that require reduction in cable installation work.

There are two classes of these unbalances:

SIDE-TO-SIDE capacitance unbalance, being the unbalance between the two side circuits of a quad, and,

PHANTOM-TO-SIDE capacitance unbalances, being the unbalances between the phantom circuit and the side circuits of a quad. (There are two phantom-to-side unbalances in a quad, phantom to the white side circuit, and phantom to the black side circuit.)

5.04 Each of these unbalances represents a certain inequality of the quad capacitances shown in Figure 6, or, as more conveniently illustrated, in Figure 8 below.

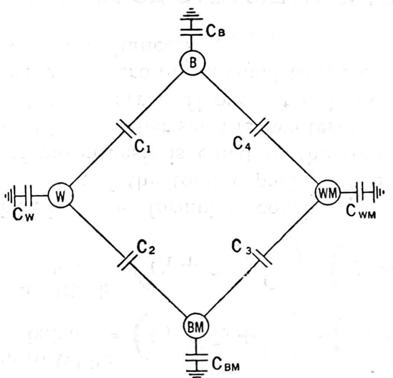


Fig. 8.

CABLE CAPACITANCE UNBALANCES

5.05 Figure 8 is equivalent to Figure 6 but with the four wires of the quad arranged to form the points of a square and to be viewed from the end rather than from the side. The unbalances may be illustrated in the form of formulas as follows:

$$\text{Side-to-Side Unbalance} = (C_2 + C_4) - (C_1 + C_3)$$

$$\text{Phantom-to-White Side Unbalance} = \left(C_1 + C_2 + \frac{C_W}{2}\right) - \left(C_3 + C_4 + \frac{C_{WM}}{2}\right)$$

$$\text{Phantom-to-Black Side Unbalance} = \left(C_1 + C_4 + \frac{C_B}{2}\right) - \left(C_2 + C_3 + \frac{C_{BM}}{2}\right)$$

5.06 Each of these formulas consists of two terms in parenthesis; if the total capacitance of the condensers in one set of parenthesis is equal to the total capacitance of the condensers in the other set, the two terms cancel each other and the unbalance is zero. If one set is larger than the other the unbalance is not zero but is equal to the difference between the two sets of capacitances.

6. MEASUREMENT OF CAPACITANCE UNBALANCES

6.01 The apparatus (3-A or 4-A capacity unbalance set) used for measuring capacitance unbalances consists of certain variable condensers and auxiliary units by means of which capacitance can be added between the proper wires of a quad to equalize the two sets of condensers shown in the formula for the particular unbalance being measured. The variable condenser for adding this capacitance is labeled "U" in Figures 9 and 10 to be referred to below. A scale on the set indicates how much capacitance is added and this is the value of the unbalance. The unit in which the unbalance is measured is the micro-microfarad, which is generally abbreviated "mmf." In order to tell when the right amount of capacitance is added, a tone (supplied by the 11-A oscillator) is sent out over one circuit and a listening test is made on the other circuit by means of a receiver connected to that circuit. When the unbalance is zero none of the tone will be transferred by crosstalk to the disturbed circuit and consequently no tone will be heard in the receiver.

Phantom-to-Side

6.02 A simplified arrangement of the capacitance unbalance set connected to a cable quad and arranged for measuring the unbalance between the phantom circuit and the white side (pair W-WM) is illustrated in Figure 9.

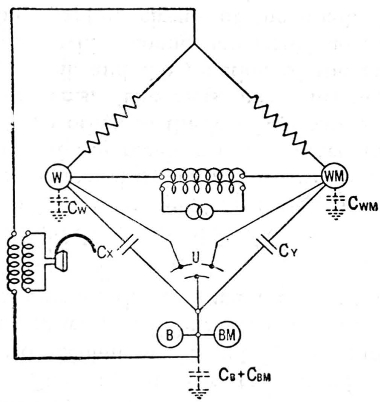


Fig. 9.

Measurement of Capacitance Unbalances

6.03 The two wires of the black side, which are short-circuited during a phantom-to-white side measurement, are brought together to form one corner of a Wheatstone bridge circuit, and the cable capacitances are combined for simplicity into two capacitances, C_x and C_y, each of which forms one arm of the bridge. The other two arms of the bridge are formed by resistance arms, which are part of the measuring set. The capacitances to ground of the wires, though taken into account by C_x and C_y, are shown in dotted lines, the reason for which will become evident in later articles. Under this arrangement the formula for phantom-to-side unbalance becomes $C_x - C_y$.

6.04 As will be noted, the oscillator is connected across the W-WM pair in very much the same manner as a transmitter would be connected during a conversation over this side circuit. One side of the receiver is connected to the shorted B-BM pair and the other to the W-WM pair at the junction of the resistance arms. The resistance arms may be considered a repeating coil, and the junction of the arms the mid-point of the coil at which connection would normally be made for deriving the phantom circuit of the quad. The receiver then is in effect connected to the phantom of the two pairs and any tone heard will indicate a transfer of energy from the side circuit (W-WM pair) to the phantom, or in other words, white side-to-phantom crosstalk. If the receiver and oscillator were reversed, the tone would then be heard on the side circuit and in about the same volume as before, indicating that phantom-to-white side crosstalk also would result. The severity of this crosstalk depends among other things on the magnitude of the unbalance existing between the circuits concerned.

6.05 It is of interest to note here that the testing apparatus standard for field work measures side-to-phantom rather than phantom-to-side unbalance. The first term implies crosstalk from the side to the phantom circuit and the second, crosstalk from the phantom to the side, and as stated above both of these types of crosstalk will exist and in about the same magnitude. Either term may therefore be used to express the unbalance condition, but "Phantom-to-side" is the one in more general use.

Side-to-Side

6.06 A modified diagram of connections for the side-to-side arrangement is shown by Figure 10.

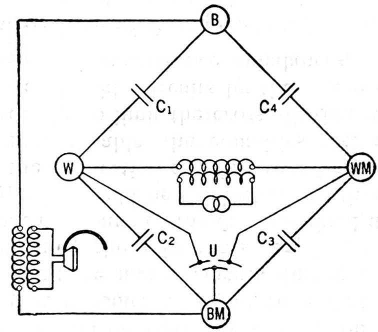


Fig. 10.

6.07 In this case no resistance arms are used, the four wire-to-wire capacitances forming the four arms of the bridge. The oscillator is connected to one pair and the receiver to the other pair. If an unbalance exists, a tone will be heard in the receiver, indicating a transfer of energy from the W-WM pair to the B-BM pair; and as each of these pairs represents a talking circuit, it is evident that if a conversation were carried on over the W-WM pair it would be heard to some extent by a party listening on the B-BM pair, or in other words, there would be crosstalk from the W-WM to the B-BM pair. The reverse also would be true and of the same magnitude, and in both cases the amount of the overheard conversation would depend, among other things, on the magnitude of the unbalance.

Purpose of Measurements

6.08 A reference to Figures 9 and 10 and to the formulas of unbalance indicates that if two quads under test had capacitances of such values that when connected together $(C_2 + C_4)$ would equal $(C_1 + C_3)$, and C_x equal C_y for both phantom-to-white and phantom-to-black conditions, the resulting unbalances would be zero and a condition of no crosstalk would obtain. It becomes apparent then that the purpose of capacitance unbalance measurements during cable installation work is to determine the unbalances in adjacent testing lengths of cable so that by means of the data obtained it may be determined what quads should be connected together and the manner in which the connection should be made in order to obtain, to the degree practicable, the equalities just mentioned, and hence, satisfactorily to limit the crosstalk that would be caused between completed cable circuits by the action of phantom-to-side and side-to-side capacitance unbalances.

Relative Importance of Phantom-to-Side and Side-to-Side

6.09 Considering only measured unbalances, that is, unbalances as measured with the 3-A or the 4-A capacity unbalance set, 1 mmf. phantom-to-side unbalance produces approximately twice the amount of crosstalk as 1 mmf. side-to-side unbalance. This relation may be appreciated by referring to Figure 7, where it will be noted that the crosstalk current through the unbalance C_u passes through the entire winding of the coil on the phantom circuit but through only one-half of the windings on the side circuits. It is apparent from this that in the work of reducing unbalances, as will be discussed in subsequent paragraphs, the greater attention should be given to phantom-to-side values, particularly in those cases where one type of unbalance can be reduced only at the cost of increased magnitude in the other.

7. TYPES AND LOCATION OF CABLE SPLICES

7.01 For purposes of capacitance unbalance tests, individual loading sections of cables are generally divided into four lengths, all equal to such degree as the location of splicing points will permit. The splices falling within these quarter lengths are completed prior to the beginning of the capacitance unbalance testing, and as these are made without tests they are called non-tested or random splices. The quads at these points, however, are mixed as thoroughly as practicable within their respective groups in order to prevent two quads from being adjacent for long lengths and hence to prevent excessive quad-to-quad crosstalk.

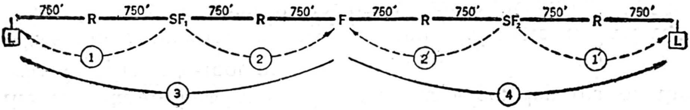
7.02 Capacitance unbalance tests are made at the junctions of the quarter lengths of loading sections. Since the quads are then connected in the manner shown desirable by the test data obtained, the splices at these points are referred to as test splices. The layout of splicing points is furnished as part of the instructions for individual jobs, but a brief discussion here may be of help.

7.03 Considering toll cable for example, a loading section of which is usually 6000 feet in length, three test splices are required in each loading section, these occurring at quarter points, that is, at the approximate 1500, 3000 and 4500-foot points. With the cable open at the half or mid-point and loading points, tests are made on the 1500-foot lengths both ways from the 1500 and 4500-foot points. These tests are called the semi-final tests and upon their completion the adjacent 1500-foot lengths are spliced together in accordance with the test data, thereby making two 3000-foot lengths of the original four 1500-foot portions.

7.04 On completion of the two semi-final tests, a final test is made at the 3000-foot point. Here measurements are made on each of the two 3000-foot lengths, and then these two lengths are spliced together to give the lowest unbalances, thus making the section a continuous 6000-foot length of cable.

Types and Location of Cable Splices

The section is still open at each end, that is, at the loading points.

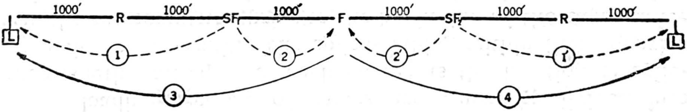


R = Random Splice
SF_1 = Semi - final Test Splice
SF_2 = Semi - final Test Splice
F = Final Test Splice
L = Loading Coil

Fig. 11.

7.05 A layout of a 6000-foot loading section of cable, showing the type and location of test points is shown by Figure 11. The two semi-final tests are indicated by SF_1 and SF_2; the length of cable tested and the direction of test, by the dashed arrows; and the order of tests, by the figures in circles. The order numerals for the two semi-finals are the same, indicating that these two tests are made more or less interdependently, the reason for which will later be seen. The final test is indicated by F, and the direction of test, etc., by the solid arrows.

7.06 If the cable were installed in 1000-foot lengths instead of 750-foot lengths as in Figure 11, the layout would be the same as Figure 11 with the exception that the semi-final tests would fall between 1000 and 2000 foot lengths rather than between 1500-foot lengths. The splicing layout would be as shown by Figure 12.



R = Random Splice
SF_1 = Semi - final Test Splice
SF_2 = Semi - final Test Splice
F = Final Test Splice
L = Loading Coil

Fig. 12.

7.07 In some cases the loading coils may be spaced at 3000-foot intervals. Three test splices per loading section can be made in such cases, in the same manner as indicated by Figure 11. The only differences are that there would be no random splices and the testing lengths would be only one half of those in the 6000-foot section.

7.08 If the cable for 3000-foot loading sections were installed in 1000-foot lengths there would be only three lengths per section and only two splicing points between loading coils for making unbalance tests. One method of test splicing under such conditions is illustrated by Figure 13.

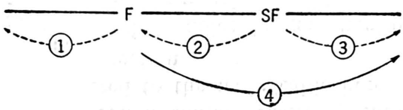


Fig. 13.

As shown by this figure, the unbalances of one of the end lengths are measured first. The unbalances of the remaining two lengths are then measured and these lengths spliced together to give unbalances that will most effectively neutralize those of the first length. The unbalances of this resulting 2000-foot length are measured again at (F), and the 1000- and 2000-foot lengths spliced together to give the lowest overall unbalances practicable.

7.09 Capacitance unbalance tests are confined to individual loading sections and consequently no measurements are required when one loading section is connected to another. The reason for this is briefly as follows: In the usual capacitance unbalance work an unbalance in one length of cable is associated with a capacitance unbalance in an adjacent length in such manner that the crosstalk produced by one unbalance is made approximately equal but opposite in direction to that produced by the other, so that the components tend to cancel each other. If, however, a loading coil intervened between the two cable lengths, the crosstalk current from one length in passing through the coil, would be changed in phase and would not, therefore, be opposite in direction of flow to the crosstalk current from the other length, so that the crosstalk currents from the two lengths would not effectively cancel each other.

7.10 Fractional loading sections, such as will be found adjacent to offices at which the cables terminate, and short non-loaded quadded cables are in general treated as full sections as regards capacitance unbalance tests, that is, a section of this kind is divided into four portions, all equal in length in so far as this is practicable without cutting the cable, and three tests are made in the manner described above. The number of cable reel lengths involved in specific instances may, however, necessitate some departure from this practice. With two lengths, for example, a single final test at the junction of the two is the obvious procedure. When three lengths are involved the procedure of Figure 13 may be followed. By reason of their close proximity in many cases to circuit terminals, fractional loading sections are of relatively large importance from a crosstalk viewpoint and warrant more than usual care in capacitance unbalance reduction work.

7.11 Terminating or tip cables that connect an office to the final loading section contain relatively high unbalances and should be connected to the main cable before test splices are made in the final section.

7.12 Non-loaded quadded cables longer than 6000 feet are usually divided up for unbalance tests into sections that would exist if loading were present.

7.13 Submarine cables are generally manufactured in relatively long lengths and contain therefore correspondingly large unbalances. To obtain satisfactory reduction in the unbalances, since test splices are undesirable when splices are not required for other reasons, it is often necessary to make use of balancing cables (described in Section G72.226). When more than one reel length is involved test splices between lengths are practicable and in some cases are sufficient to effect the desired unbalance reduction. Where this is not the case balancing cable may be used as a supplementary measure for accomplishing the further reduction required. The procedure in such cases will be covered by local instructions.

7.14 If portions of land cable are connected to the submarine, the capacitance unbalance procedure to be followed may depend upon such factors as the relative lengths of the cables, so that each case of this kind will be covered by local instructions. It might be desirable in some cases, for example, to balance the land and submarine portions independently and then connect the portions together, by test splicing if necessary; while in others, the best procedure might possibly be to build up the land portion unbalances to values to meet the submarine and thus avoid the use of balancing cables. The overall unbalances in sections containing submarine cable should in general conform to the same limit that would be observed if only land cable were involved.

7.15 It is occasionally necessary to locate adjacent loading coils with closer spacing than normal, requiring that capacitance be connected to the cable quads in sufficient amount to build out the quad capacitance to that of quads of full loading section length. This building-out is generally accomplished by using for part of the section a cable having twice the number of quads required. One quad in this cable is connected at each end to a quad of the main cable, and an adjacent quad is left open at one end of the building-out cable and bridged on to the first quad at the other end. Thus, a 100-foot length of such cable would be equivalent in capacitance to 200-feet of main cable. The exact manner in which the cable is used, and the best procedure for test splicing, vary with jobs depending on such factors as the amount of building-out cable involved and the position it occupies in a loading section. In general, however, building-out cable is assumed to be twice its actual length and test splices laid out as previously discussed for regular cable.

8. CAPACITANCE UNBALANCE LIMITS

8.01 An appreciation of the value of capacitance unbalance testing is gained through a comparison between the unbalances that would exist in a 6000-foot section if no testing were done (all random splices) and those that do exist on the completion of three test splices. Such a comparison is given in the following table.

Type of Unbalance	Average Unbalance—6000 Ft. Section: No Test Splices	Average Unbalance—6000 Ft. Section: 3 Test Splices
Phantom-to-Side	100	7
Side-to-Side	50	10

From this it is noted that a better than 10 to 1 reduction is effected in the phantom-to-side, and a 5 to 1 in the side-to-side.

8.02 The actual values which are used for guidance in work performance, are called limits. The limits of capacitance unbalance for both toll and toll entrance cable generally observed in construction work are given in the tables below. Two types of limits are given: (1) AVERAGE, corresponding, say, to the sum of all the phantom-to-side unbalances (neglecting signs) of a group divided by the number of unbalances; and (2) MAXIMUM, which as the name implies, is the nighest unbalance of the type involved.

TOLL ENTRANCE CABLE LIMITS—MEASURED CAPACITANCE UNBALANCE (mmf.)

Type of Unbalance	6000 Ft. Loading Sections: Average	6000 Ft. Loading Sections: Maximum
Phantom-to-Side	7	100
Side-to-Side	10	100

TOLL CABLE LIMITS—MEASURED CAPACITANCE UNBALANCE (mmf.)

Type of Unbalance	6000 Ft. Load Sections: Ave.	6000 Ft. Load Sections: Max.	3000 Ft. Loading Sections: Ave.	3000 Ft. Loading Sections: Max.
Phantom-to-Side	7	50	5	35
Side-to-Side	10	70	7	50

These values are based largely on performance results for cable installed in 750-foot lengths. Experience indicates that the same 6000-foot values can readily be met with 1000-foot reel lengths, but that the 3000-foot values (two test splices per section) may be exceeded one or two mmf. In each case, especially in the latter, more built-up unbalances will be required.

8.03 It is desirable of course to reduce loading section unbalances as much as practicable, so that the limits tabulated above should be regarded as figures for guidance rather than for strict adherence. The limits are, however, consistent with results obtained on various cable installations, and the only difficulty likely to be experienced will be with occasional maximum values and with average values when the quad groups are small.

8.04 Where toll entrance cables, intermediate cables, or very short toll cables are involved, consideration of the economy in construction work may justify the adoption of somewhat less severe average limits. It is suggested however, that revised average limits for these cases not exceed twice those recommended above.

8.05 Maximum values obtained on representative installations only occasionally exceed 30 mmf. The maximum values given in the table above have been made higher than this, not with the thought of recommending the general observance of higher values but rather for the purpose of indicating when balancing pairs should be applied (the use of balancing pairs is discussed in Section G72.226).

8.06 As will be mentioned in a later part of the section, it is very important that close cooperation be established between testers at the two semi-final test points of a loading section in order that unbalances may be built-up in one half of the section to neutralize occasional high unbalances that may exist in the second half after the test splice in the second half has been completed. In view of this it is impracticable to set limits for semi-final resultants, but these resultants, except when purposely built-up, obviously should be made as small as practicable.

8.07 Excessively high unbalances found during semi-final tests can in the usual case be substantially reduced by means of the building-up process, and balancing pairs applied at the final splices for obtaining further reduction. Unbalances of this nature are caused in large part by very high unbalances in individual reel lengths, and it is to be noted that reduction might also be obtained by opening the reel lengths approximately at their centers and making test splices at these points in the offending quads. This method is generally effective but is impracticable for underground cable.

9. TESTING AND SPLICING PROCEDURE

Preparation of Cable for Test

9.01 The cable must be properly prepared prior to the testing. This part of the work is performed by the splicing forces and in accordance with instructions issued. Briefly, the quads are cleared of crosses, grounds, and leaks and left open at the distant end of the cable length to be tested and at the testing point are brought out by groups to numbered holes in perforated test boards made of such material as rubber, leather or cloth. This testing point procedure is generally referred to as "boarding" the quads. One or more of the boards is used for each group, and each quad threaded through a separate hole. The wires are than cut "long and short," that is, one wire of each pair is cut an inch or two shorter than its mate in order properly to identify the two, such identification being required for the reason that the two wires of a pair have the same color of insulation.

Capacitance Unbalance Measurements Required

9.02 As mentioned earlier, this section deals specifically with phantom-to-side and side-to-side unbalances, since these are the unbalances to which test splicing in the usual case is confined. With the testing limited to within-quad unbalances, a group of three measurements is made on each quad in each direction from a test point, these being (1) phantom-to-white side, (2) phantom-to-black side, and (3) side-to-side unbalance measurements. Since there are in the general case three test splices per loading section, a total of six groups of measurements (preliminary measurements, that is, preliminary to splicing the quads together) will be required per loading section for each quad in the cable. In addition to these groups of tests and as explained later under "Check Tests," a group of check tests is made at each of the test points after the quads in the two directions from the test point have been spliced together in the manner shown desirable by the preliminary measurements.

Splicing Diagrams

9.03 After the unbalances in two portions of cable to be connected together have been measured, and recorded on the data sheet as described later, the unbalance data must be studied in order to determine the manner in which connections should be made in order to obtain the greatest practicable neutralization in the combined unbalances of the two portions. This studying of the unbalances is commonly called "matching" quads or "doping" the unbalance sheets.

9.04 When quads of one portion of cable are spliced to those of another, the four wires of one quad must be connected to the four wires of another, that is, THE QUADS MUST NOT BE SPLIT; and the two wires of one pair must be connected to the two wires of another pair, that is, THE PAIRS MUST NOT BE SPLIT. With these limitations, there are eight possible ways in which two quads may be connected. First, the pairs may be connected straight, white to white and black to black and the wire of each pair may be connected straight (long to long and short to short) or either of the pairs or both pairs may be transposed, thus giving four possible combinations. Four other combinations may similarly be obtained with the pairs reversed, white connected to black and black to white. These eight possible combinations are shown diagrammatically by Figure 14.

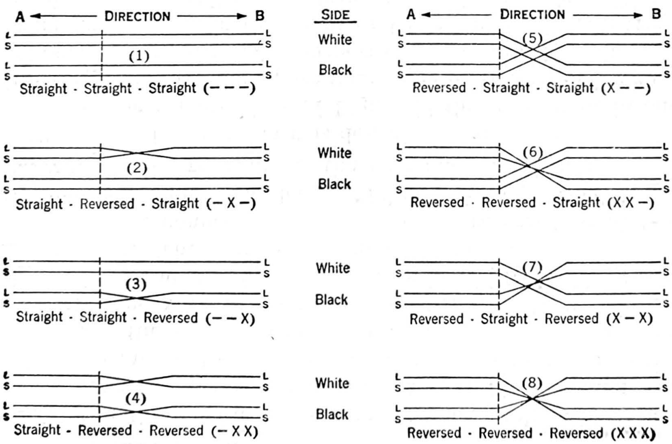


Fig. 14.

9.05 The three-word name accompanying each combination describes the connections: the first tells whether the pairs are connected straight (white to white) or reverse (white to black); the second, whether the white pair is connected straight (long wire to long wire) or reversed (long wire to short wire); and the third the manner in which the black pair is connected. The symbols (X) and (—) also are used for describing these connections, (X) meaning "reversed," and (—) meaning "straight." The letters "L" and "S" appearing on the diagrams denote respectively the long and short wires.

9.06 To avoid confusion it is desirable to assume as indicated by the vertical lines of Figure 14 that the quads in one direction, say Direction A, are unaffected by the various combinations, that is, that all transpositions called for by the diagrams are inserted in the quads of Direction B. Thus a transposed white pair will mean a transposition in the pair of Direction B that is connected to the white pair of Direction A, whether the Direction B pair is white or black. Considering combination (6) for example, since the transpositions are reckoned from Direction A, the description is as shown, "reversed-reversed-straight" or "XX—", but reckoned from Direction B, the proper description would be "reversed-straight-reversed." Directions may be chosen as desired, provided the resultant unbalances to be mentioned later are properly computed and provided also the testers and splicers interpret alike the code used. It has been found desirable, however, to work from left to right with the splicing diagrams, assuming the unbalances of the quads forming the left halves of the diagrams to remain unchanged. The reason for this will become more evident under the discussion of data sheets.

Neutralization of Unbalance

9.07 Considering first the side-to-side unbalance: The four terminals shown in Fig. 10 represent the wires of a quad, and the condensers the capacitances that exist between the wires; and it is readily seen that the connection of another quad to this one would superimpose the capacitances of the two, or in other words, the condensers of the second quad would be placed in parallel with those of the first. Thus, with a "straight-straight-straight" combination, two C_1's (not necessarily equal to each other) would be connected in parallel, two C_2's in parallel and the like. The resultant capacitance network could, therefore, be represented by a diagram identical to Fig. 10 in form but having larger capacitances in the four arms. By transposing the connections between the two quads the capacitances of one may be added in various combinations to those of the other, so that it is possible, for example, to associate high capacitance condensers in one direction with low capacitance condensers in the other direction and thus eliminate large differences in the branches of the combined network.

9.08 It will be well at this point to have clearly in mind the distinction between unbalances as regards their signs. The capacitances involved in a quad of wires as regards the crosstalk problem are shown in Fig. 8 and it has been mentioned that if a conversation were being carried on over one circuit of the quad and if certain inequalities existed in the capacitances, a portion of the voice currents would be transferred to the other circuits, appearing therein as crosstalk current. The inequality of capacitances may be such as to cause this crosstalk to flow in one direction around the circuits or it may be of a nature to cause current flow in the other direction, but assuming the same magnitude of current the resulting crosstalk is independent of the direction of flow. If, however, it is desired to oppose the crosstalk current in one portion of a circuit by that in an adjacent portion and thus tend to cancel the overall effect of the two, it becomes necessary to recognize the relative directions of the currents. This has been done by giving signs to the unbalances that cause the crosstalk current to exist, like signs indicating the same direction of flow whether in one direction or the other around the circuit. Thus, positive signs indicate one direction and negative signs the opposite.

9.09 As will be noted from the side-to-side unbalance formula in paragraph 5.05, the difference, $(C_2 + C_4)—(C_1 + C_3)$, must be a positive quantity if the sum of the capacitances C_2 and C_4 is larger than the sum of C_1 and C_3. Likewise, for the phantom-to-side condition, the difference, $C_x - C_y$, must be a positive quantity if C_x is larger than C_y. With these conditions the unbalance, C_u, is considered a positive unbalance. If, on the other hand, the term preceded by a negative sign in each of the three formulas were the larger, the difference in each case would be a negative quantity and the unbalance would be considered negative. It is seen from this that the assignment of signs is purely arbitrary, and that if desired the phantom-to-side unbalance could be called $C_y - C_x$ and the side-to-side called $(C_1 + C_3)-(C_2 + C_4)$, in which case it is evident that the signs would be the reverse of those mentioned above. A uniform method of applying signs is necessary, and the assignment has, therefore, been made in accordance with the formulas referred to, and the unbalance set has been designed to indicate accordingly.

9.10 If $(C_2 + C_4)$ of a quad in Direction A, for example, were 10 mmf. greater than $(C_1 + C_3)$, the side-to-side unbalance (C_u) by the formula would be +10 mmf. Also, if $(C_1 + C_3)$ of a quad in Direction B were 10 mmf. greater than $(C_2 + C_4)$ the unbalance in this direction would be —10 mmf. Therefore, if these two quads were connected "straight-straight-straight," the combined $(C_2 + C_4)$'s would be equal to the combined $(C_1 + C_3)$'s and the unbalance would be zero. If on the other hand, $(C_2 + C_4)$ in Direction B were 10 mmf. larger than $(C_1 + C_3)$ in this direction and the connection of the quads made as before, both of the high values, the $(C_2 + C_4)$'s would be added together, giving a resultant capacitance 20 mmf. greater than the combined $(C_1 + C_3)$'s, and C_u therefore would be +20 mmf. Suppose in this case the quads were connected "straight-straight-reversed." As seen in Fig. 10, $(C_2 + C_4)$ and $(C_1 + C_3)$ of Direction B would then be added to $(C_1 + C_3)$ and $(C_2 + C_4)$ respectively, of Direction A, thus combining in both cases one of the high capacitances with one of the low capacitances and consequently reducing the unbalance to zero.

9.11 Letting Fig. 9 represent a quad in Direction A arranged for a phantom-to-white side test and assuming C_x to be 10 mmf. greater than C_y (C_u = +10 mmf.): If this quad were connected by a "— — —" combination to one in Direction B having C_y greater by 10 mmf. than C_x, (C_u = —10 mmf.) the two C_x's would be placed in parallel and the two C_y's in parallel, thereby combining one of the high and one of the low capacitances in each arm and therefore equalizing the two bridge arm capacitances and eliminating the phantom-to-white unbalance. Inasmuch as the black pair is shorted out for the test, a transposition in this pair would not affect the phantom-to-white unbalance, and a "— —X" combination would give the same phantom-to-white neutralization. The reversal of the black pair would, of course, affect the resultant phantom-to-black unbalance.

9.12 Letting the Direction A quad remain as above (phantom-to-white unbalance = +10 mmf.) and assuming the Direction B quad likewise to have a +10 mmf. phantom-to-white unbalance (C_x greater by 10 mmf. than C_y), the "— — —" or "— —X" combination would add the two high capacitances in the C_x arm and the two low ones in the C_y arm, and the difference between the two arm capacitances would be 20 mmf. giving a resultant phantom-to-white unbalance of +20 mmf. Either the "—X—" or the "—XX" combination in this case evidently would equalize the bridge arm capacitances and thereby eliminate the unbalance. Similarly, if the Direction B quad had a phantom-to-black unbalance of —10 mmf. the "X — —" or "X — X" connection to the A quad would also equalize the bridge arm capacitances and the phantom-to-white pair unbalance would be zero. The neutralization in the latter case is associated with the phantom-to-white rather than the phantom-to-black unbalance because it is the unbalance of Direction A that is used as the reference.

9.13 It should be noted here that Fig. 9 may readily be converted to the phantom-to-black side condition by merely interchanging the W and B wires and the WM and BM wires.

9.14 From the above considerations and from further study of Figs. 9 and 10 it may be generalized that the capacitance unbalances of two quads to be spliced together will add to or subtract from each other, depending upon the splicing combination used, and further that:

(a) If two pairs, one in each direction from a test point, are connected together straight, long wire to long wire and short wire to short wire, the resultant unbalance between the phantom and the pair of the total length thus formed will be the algebraic sum of the two component phantom-to-side unbalances involved.

(b) If two pairs, one in each direction from a test point, are connected together reversed, long wire to short wire and short wire to long wire, the resultant phantom-to-side unbalance will be the algebraic difference of the two component phantom-to-side unbalances.

(c) If the two pairs of one quad are connected alike (both straight or both reversed) to the two pairs of another quad the resultant side-to-side unbalance will be the algebraic sum of the two component side-to-side unbalances. (This rule holds whether a white pair is connected to a white or to a black pair.)

(d) If the two pairs of one quad are connected differently (one straight and the other reversed) to the two pairs of another quad, the resultant side-to-side unbalance will be the algebraic difference of the two component side-to-side unbalances. (This is true whether a white pair is connected to a white or to a black pair.)

Note: It is helpful for a clear understanding of the above rules to draw sketches similar to those of Figs. 9 and 10 and note exactly how the capacitances combine when the quads are connected together in the various possible ways. Consider, for example, rule (c) for the condition of reversals in both pairs. Draw a sketch representing the four wires of a quad and its capacitances, as in Fig. 10 omitting for clearness the oscillator and receiver branches. Let this represent a Direction A quad. On the inside of the square thus formed draw a similar one to represent a Direction B quad and so designate the wires of this quad that its WM wire is adjacent to the W wire of the Direction A quad, W to WM, B to BM and BM to B. The capacitances of the Direction B quad must of course be designated in accordance with Fig. 10, for example, the capacitance between its W and B wires will always be C_1 regardless of the position of the wires. Now, connect the points of one square to the adjacent points of the other. This evidently is equivalent to connecting the two quads together with a reversal in each pair. From the finished sketch, it will be seen, for example, that C_{4B} (capacitance C_4 of the Direction B quad) is connected in parallel with C_{2A} and it will be remembered from the side-to-side unbalance formula that both of these capacitances are preceded by "+" signs. Similarly, in each of the other three branches two capacitances are paralleled which are preceded by the same sign in the formula. In other words, the capacitances add without change of signs and the resultant unbalance will be the algebraic sum of the two side-to-side components.

9.15 From the following examples of algebraic sum and difference, it will be noted that when two signs precede a value the resultant sign is positive if the two are the same and negative if the two are different.

VALUES		ALGEBRAIC SUM	ALGEBRAIC DIFFERENCE
+20	—10	(+20) + (—10) = +10	(+20) — (—10) = +30
+20	+10	(+20) + (+10) = +30	(+20) — (+10) = +10
—20	+10	(—20) + (+10) = —10	(—20) — (+10) = —30

9.16 The effect of each of the splicing combinations on resultant unbalances is illustrated in the following example, the unbalance values for a quad in two directions being assumed:

DIRECTION A			DIRECTION B		
PH.-TO-SIDE		SIDE TO SIDE	PH.-TO-SIDE		SIDE-TO-SIDE
WH.	BL.		WH.	BL	
+30	—15	—5	—15	+50	+10

SPLICING DIAGRAM	CALCULATED RESULTANT		
	PH.-TO-SIDE		SIDE-TO-SIDE
	WH.	BL.	
— — —	+15	+35	+ 5
— × —	+45	+35	—15
— — ×	+15	—65	—15
— × ×	+45	—65	+ 5
× — —	+80	—30	+ 5
× × —	—20	—30	—15
× — ×	+80	0	—15
× × ×	—20	0	+ 5

9.17 As noted from this example, one combination will be found that gives the most satisfactory neutralization (the "×××" combination in this case), but it is quite evident that the proper combination may readily be determined by inspection rather than by applying the eight possible combinations and noting the resultant effects. The fact that unbalances add or subtract directly, indicates that two quads to be connected together should be so selected that the phantom-to-side and side-to-side unbalances of one will be of the same order of magnitude as the corresponding unbalances of the other. This, however, does not require that the two phantom-to-white or the two phantom-to-black unbalances be of the same order of magnitude, for as previously seen, the phantom-to-white unbalance of one quad may be associated with the phantom-to-black of another, or the reverse, through the use of an appropriate splicing combination.

9.18 Since phantom-to-side unbalances are usually larger and more undesirable from a crosstalk standpoint than side-to-side unbalances, it is desirable when splicing a group of quads to select first the quad having the highest phantom-to-side unbalance and connect this quad to the one in the other direction that has a phantom-to-side unbalance of about the same magnitude. The quads having the next largest unbalances should be selected and spliced and so on through the list.

9.19 Two quads having one high phantom-to-side unbalance each, may have other unbalances of such magnitudes that these will not be satisfactorily neutralized. In such cases other quads should be examined for more appropriate unbalances, it being often desirable to obtain slightly less complete neutralization in the highest value if this means appreciably better neutralization of the others.

9.20 In the above, only the magnitude of unbalance has been considered, it being assumed that by the use of the proper diagram the three unbalances of one quad may be made opposite in sign to the three unbalances of another, thus obtaining reduction in all. As will be seen in the article to follow, this will not be the condition unless certain other rules are followed in the selection. It will, nevertheless, be necessary in many instances to select two quads of improper signs in order to reduce a high phantom-to-side value, and in such instances, as will later be seen, only one of the remaining two unbalances can be reduced. In determining in such cases, which of the remaining two should be reduced, it should be remembered that:

(a) A phantom-to-side unbalance produces about twice the amount of crosstalk caused by a side-to-side unbalance of the same magnitude; and that:

(b) In the case of semi-final tests there will be later opportunities (final test) to obtain further reduction, and since there are two phantom-to-side unbalances and only one side-to-side in each quad, twice the number of chances are offered for reducing a phantom-to-side value as are offered for reducing the side-to-side.

9.21 In view of these conditions, it has been found desirable at semi-final tests, assuming one of the phantom-to-side unbalances to have been reduced, to lower the remaining phantom-to-side unbalance in preference to the side-to-side when the sum of the two phantom-to-side components to be combined (signs not considered) is larger than the sum of the two side-to-side components. At final tests the phantom-to-side should be reduced in preference to the side-to-side if the sum of the phantom-to-side components is more than half as great as the sum of the side-to-side components.

Positive and Negative Quads

9.22 If all possible combinations of signs that the three unbalances of a quad may have are examined, it will be found that only eight exist and that these may be divided into two significant groups of four each as follows:

Positive Quads			Negative Quads		
Ph.-to-side			Ph.-to-side		
Wh.	Bl.	Side-to-side	Wh.	Bl.	Side-to-side
+	+	+	—	—	—
+	—	—	—	+	+
—	+	—	+	—	+
—	—	+	+	+	—

9.23 The two groups or classes of quads as regard the unbalance signs have been termed "positive" and "negative" quads respectively, for the reason that the product of the three signs of any combination of the "positive" group gives a positive sign and, similarly, the product of the three signs of any combination of the other group gives a negative sign. It can be shown that by properly altering the testing lead connections to a quad, the signs of the unbalances of the quad as indicated by the testing set may be changed to those of any other combination of the same class, but that no possible change of leads will change the signs to a combination of the other class.

9.24 As will be seen from the table, the signs of a positive quad combination are opposite to corresponding signs of the negative quad combination in the same horizontal line. Therefore, if two quads, one in each direction, gave such results, their unbalances would tend to neutralize each other if the quads were connected "straight-straight-straight." If the quads were in different classes but not in the same horizontal line, it is evident that by the use of the appropriate splicing diagram this same tendency towards neutralization could be obtained. If, however, the quads to be connected together are in the same class, it will be possible to obtain neutralization in only two of the three unbalances.

9.25 A ready way of determining whether two quads will go together in such manner as to effect neutralization in all three unbalances is to add up either the positive or the negative signs: if the sum is an odd number the quads will necessarily be of different classes and the condition for neutralization of the three unbalances will obtain. Assume for example that a quad in Direction A has two "+" signs. To find a quad in Direction B that from the viewpoint of signs alone will go with this quad most favorably, it is necessary merely to run over the unbalance data of the Direction B quads and select any quad that has either one or three "+" signs.

9.26 If one or more of the three unbalances of a quad is zero, the quad may be considered neutral and placed in either class, this meaning that such a quad may properly be connected to a quad of either class. It is obvious, of course, that in such cases the quad to which a neutral quad is connected should have a relatively low unbalance to combine with the zero value.

9.27 In addition then to the requirement that the three unbalances of a quad should be of the same order of magnitude as those of the quad to which it is to be connected, the two quads should be of different classes if greatest neutralization is to be accomplished. A few simple applications of these general rules are given in later paragraphs and a more extensive application is shown on the data sheets discussed in Part 10.

Built-up Unbalances

9.28 During semi-final tests unbalances are often found with such magnitude that they cannot be adequately neutralized at the semi-final splice itself, requiring that unbalances of like magnitude be built-up at the other semi-final splice of the same loading section so that neutralization of the high values may be obtained at the final test point. For this reason better results will be obtained at a final splice if the two associated semi-final tests are made dependent on each other.

9.29 When testing is done simultaneously at the two semi-finals of a loading section the testers should notify each other of any high resultant unbalances remaining, and necessary steps should be taken to build-up unbalances required for satisfactory neutralization. As is usually done in a procedure of this kind, the testers of the two points, after the unbalances have been measured, get together for "doping" the data sheets, and they can thus quite easily care for any resultant high unbalances found at either semi-final point. Generally, in order that the work may be performed most economically, the first group of quads is boarded, cut long and short, and measured. Then, while the splicers are preparing the remainder of the cable the testers can be "doping" the first group. After the remainder of the cable is measured, splicing can begin on the first group while "doping" is under way on the others. Large groups are rather cumbersome for "doping," and some companies have found it expedient to divide a group containing about 60 quads or more into two groups and treat the two independently. Where groups are divided at final splices it may be necessary, on account of possible built-up unbalances, to interchange a few quads between the half groups after the unbalances have been measured. The necessity for this is to get associated built-up and to-be-met unbalances in the groups to be spliced together.

9.30 If the semi-final tests are not made simultaneously, the tester making the first test should make special note under "observed resultant" of the magnitudes and signs of such high unbalances as may be found. The data sheet should then be turned over to the tester assigned to the second semi-final point, and he should endeavor to produce unbalances, if they do not naturally occur, that will neutralize the high values found at the first semi-final. If the resultant unbalances at the first point are unusually low, arrangements should be made to leave at that point two or three quads with moderately high unbalances from phantom to one side and from side-to-side to neutralize high unbalances that possibly will occur at the second point. If it is later found that these unbalances will not be needed, the tester at the second semi-final splice can easily build-up unbalances to neutralize them.

9.31 When unbalances are purposely added or built-up, both magnitudes and signs of resultants should be carefully recorded, and assurance made that the resultants will properly combine at the final test splice with the resultants of the quads in the other direction whose unbalances are to be reduced. This means that the unbalances of one quad should have approximately the same magnitudes as corresponding unbalances of the quad to which it is to be connected, and that the two quads should fall in different classes. In some instances it has been found advantageous to avoid the necessity of coordinating relative signs at the associated semi-final test points. This is accomplished by splicing the quads requiring the building-up procedure in such manner as to place the resultant quads in the neutral class. Quads then built-up at the other semi-final point to meet these will also need to be in the neutral class or approximately so, but the signs of course will be of no importance. When signs are a consideration it is evident that precautionary measures should be taken to insure that the two unbalance sets used at the semi-finals will give the same signs to unbalances. No precaution is necessary to identify at the final splice the quads involved in built-up unbalances, because these, in general, will be evident from the final test data if the unbalances are of such magnitude as to require this special procedure.

9.32 In all cases where unbalances are purposely added, a notation to this effect should be entered on the data sheet. The testers at final splices may be given the data sheets for the two semi-final tests involved and the resultants of these tests compared with the final test data as a further check of the previous work.

9.33 When unbalances should be built-up (that is, how large an unbalance at one semi-final splice should be before an unbalance is produced at the other semi-final to meet it) may depend on the size of group involved, the loading section limits observed, and the splicing layout for the cable concerned. In general, considering 6000 ft. loading sections, satisfactory balances may be obtained by building-up to meet all values above about 40 mmf., the 40 mmf. representing the unbalance in 3000 feet of cable, that is, the unbalance existing on completion of the semi-final splice. For 3000 ft. loading sections, the corresponding value would be about 30 mmf.

Illustrative Examples

9.34 To briefly illustrate the principles of the foregoing paragraphs there are given below assumed capacitance unbalances for four quads in each direction from a semi-final test point, and a method of determining the quads that should be connected together and the manner in which connections should be made. In what follows, all transpositions are assumed made in the quads of Direction B, the unbalances of Direction A quads, therefore, remaining unchanged in sign in the computations of resultant unbalances.

	Direction A			Direction B			
	Ph.-to-Sd.			Ph.-to-Sd.			
Quad	Wh.	Bl.	Sd.-to-Sd.	Wh.	Bl.	Sd.-to-Sd.	Quad
1	+ 70	+ 60	—30	— 80	+ 50	—50	1
2	—105	— 30	—50	+110	— 5	+10	2
3	— 10	+120	—10	+115	— 30	—60	3
4	+ 60	+100	+60	+ 65	+200	+20	4

9.35 An inspection of the unbalances readily shows that the 200 mmf. value cannot be neutralized to any large extent with any of the values in Direction A, and that it will be desirable to obtain satisfactory neutralization in the remainder of the quads, leaving the 200 mmf. value to be treated by the "built-up" procedure. Selecting then the quad having the next largest phantom-to-side values, quad 3 in Direction A (quad 3-A), it is found that quad 3-B has a value that will give the greatest neutralization of the high phantom-to-side value, but it will be noted that both of these quads are of the same class (Positive), or in other words, that from the consideration of signs alone, the two will not go together because the sum of the six signs is an even number of both positives and negatives. It will be noted also that the two side-to-side values are considerably different. Considering quad 2-B, the magnitudes of unbalances are of the same order and the sum of either the "+" or the "—" signs is an odd number. Inasmuch as the high value of 3-A is on the black side and is positive, and that of 2-B is on the white side and also positive, the pairs must be reversed so as to connect black to white, and the two wires must be reversed so as to change one of the signs. The other two phantom-to-side values are both negative and consequently the two wires of this pair also must be reversed. This means a transposition in each of the pairs, and therefore no change in sign of side-to-side values, but since the two side-to-side values are already of different signs no change is desired. This condition then requires the "reversed-reversed-reversed" combination and the resultant unbalances will be:

Direction A	Direction B	Splicing Diagram	Calculated Resultant
—10 +120 —10	+110 —5 +10	XXX	—5 +10 0

9.36 It should be noted that like signs for the two side-to-side values would have placed the quads in the same class and that as a result it would have been impossible to neutralize more than two of the three unbalances. Even with such condition the combination shown would still be satisfactory, because the resultant 20 mmf. side-to-side unbalance would be reasonably low as compared to the neutralization obtained in the phantom-to-side values.

9.37 Taking the quad with the next highest unbalances, quad 3-B, it is seen that the values and signs go well with those of quad 2-A and that with the "straight-straight-reversed" combination the resulting unbalances will be as follows:

Direction A	Direction B	Splicing Diagram	Calculated Resultant
—105 —30 —50	+115 —30 —60	— — X	+10 0 +10

9.38 Quad 1-A if connected to quad 1-B with the "straight-straight-reversed" combination will give as resultant unbalances:

Direction A	Direction B	Splicing Diagram	Calculated Resultant
+70 +60 —30	—80 +50 —50	— — X	—10 +10 +20

9.39 The remaining quads 4-A and 4-B, involve a very high unbalance that cannot be satisfactorily reduced, and thus require that an unbalance of similar magnitude be built-up at the other semi-final splice. As both of these quads are of the same class, reduction in magnitude can be realized in only two of the unbalances. It will be best to obtain first as large a reduction as possible in the 200 mmf. value by associating this with the 100 mmf. value of Direction A. To determine then which of the remaining unbalances should be reduced, the rule previously given may be applied. The sum of the remaining phantom-to-side values (ignoring signs) is found to be 60 + 65 = 125 mmf., and that of the side-to-side values 60 + 20 = 80 mmf. Inasmuch as the tests are being made at a semi-final point and since the sum of the phantom-to-side values is the higher, it is to these values that the second possible reduction should be applied. To obtain such neutralization requires the "—XX" combination and the resultant unbalances will be as follows:

Direction A	Direction B	Splicing Diagram	Calculated Resultant
+60 +100 +60	+65 +200 +20	— X X	—5 —100 +80

9.40 The resultant unbalances will place the combined quad, as will be measured at the final splice, in the positive quad class and the unbalances to be built-up at the second semi-final should, therefore, if possible be those of a negative quad. Assuming that unbalances could be built-up with the signs and magnitudes (—105 —12 —70), a "reversed-reversed-reversed" combination at the final splice would result in the following unbalances:

DIRECTION A	DIRECTION B	SPLICING DIAGRAM	CALCULATED RESULTANT
—5 —100 +80	—105 —12 —70	XXX	+7 +5 +10

9.41 It is assumed in the last example that the unbalances as measured at the final splice have the same signs as at the semi-final splices. Since the testing clips may not be connected to the quads at the final splice wire for wire as they were at the semi-final splices, the signs may naturally be different. It is apparent though that a particular quad will be in the same sign class at both points and that through the use of the proper splicing diagram the neutralization illustrated can be effected.

9.42 At the semi-final tests, as illustrated by the above examples, measurements to the nearest 5 mmf. are accurate enough. The results of final tests represent the capacitance unbalance conditions that will exist after the cable is placed in service and these therefore warrant somewhat more accuracy. Readings in these tests may usually be taken to the nearest one or two mmf. as illustrated by the final test data given on the data sheets described in Part 10.

Check Tests

9.43 Check tests should always be made after quads are spliced to insure detection of such errors as may occur in the testing and splicing work. These tests are made in the usual manner, with the testing leads bridged on the quads at the wire joints. Unless the observed unbalances are in close agreement with the calculated resultant unbalances, the joints should be opened and the quads retested. Improper recording of signs during initial tests, incorrect "doping" of the data sheets, misunderstanding by the splicer of the splicing instructions, and incorrect calling of instructions where this practice is followed are the prevalent sources of error. Any error, of course, retards construction work and should be carefully guarded against.

9.44 Inasmuch as the method of calculating resultants leaves the signs of unbalances unchanged in Direction A, the phantom-to-white, phantom-to-black, and side-to-side observed values should check corresponding calculated values in both magnitude and sign if for the check test the testing leads are connected to the wires of Direction A in the same manner as they were connected for measuring in Direction A alone. In practice, though, the leads may be connected without regard to the original connections, care being taken merely to avoid splitting pairs and quads. The magnitudes of the observed resultants should then be approximately equal to those of the calculated (the two-phantom-to-side values may be interchanged) and the signs of the observed resultants if these are noted should fall in the same class as those of the calculated.

10. CAPACITANCE UNBALANCE DATA SHEETS

10.01 There are two standard forms for recording capacitance unbalance data, namely E-987 and E-988. Samples of these forms, both filled out with the same final splice test data, are illustrated by Figures 15 and 16 respectively. Both of these forms serve the same purpose, one type being preferred by some of the companies, the second type by others. Both forms are 8-1/2 in. x 11 in. size and are printed on light green paper.

Capacitance Unbalance Data Sheets

PRINTED IN U.S.A. FORM E 989

CAPACITANCE UNBALANCE DATA SHEET

WITHIN - QUAD UNBALANCES

CABLE (A) Culver- (B) Dorchester
ESTIMATE NO. 2010 PRINT NO. 15

LOADING SECTION 3
TEST POINT Poles 160-161
TYPE OF TEST Final

Direction A Culver Quad No.	Direction A Un-balance	Splicing Diagram	Direction B Quads Un-balance	Direction B Quads Quad No.	Resultant Unbalance Calculated	Resultant Unbalance Observed	Direction B Dorchester Quad No.	Direction B Un-balance
1	+15		+15	29	10	10	1	-12
	+10		-15		5	5		-5
	-10		-25		5	5		-5
2	+16		-18	15	2	0	2	-10
	-35		+25		10	10		-15
	+8		0		8	10		+5
3	+10		-10	31	0	0	3	-20
	-6		+10		4	5		-8
	-10		+10		0	0		-15
4	+26		+10	8	16	15	4	+20
	+20		-28		8	8		-5
	-90		-85		5	5		+15
5	0		+6	19	0	0	5	+55
	-5		-10		5	5		+10
	-10		0		4	0		+18
6	+16		-12	1	4	5	6	-15
	-8		-5		3	3		+10
	+6		-5		1	0		-12
7	-15		-15	6	0	0	7	0
	-6		+10		4	5		+10
	+6		-12		6	6		+5
8	+40		+35	21	5	5	8	+10
	+10		-10		0	0		-28
	-28		-35		7	10		-85
9	+20		-20	3	2	0	9	-40
	0		-8		8	10		0
	+10		-15		5	5		-10
10	-6		+55	5	12	12	10	+5
	-8		+10		2	2		+15
	-60		+18		5	5		+70
11	-5		-10	2	0	0	11	+5
	-16		-15		1	0		+6
	-10		+5		0	0		+6
12	-8		+5	11	3	3	12	+20
	0		+6		6	5		-10
	+6		+6		0	0		+15
13	-16		-20	22	4	5	13	0
	-8		-2		6	5		+5
	+20		-20		0	0		-10
14	+30		-10	25	0	0	14	+20
	-10		-5		5	7		+5
	0		+30		10	10		0
15	+20		+10	26	5	5	15	-18
	+20		-20		0	2		+25
	+15		+15		5	5		0
16	+25		-30	16	5	5	16	-30
	-10		-14		4	5		-14
	0		+5		5	7		+5
17	+40		-20	28	5	6	17	-16
	+20		-5		15	15		-16
	-10		+45		10	10		+5
18	+35		-30	18	5	5	18	-30
	+7		+5		2	0		+5
	-30		-40		0	0		-40
19	-10		-10	24	0	0	19	+6
	+28		-30		2	5		-10
	0		-5		5	4		0
20	+75		+5	10	5	6	20	+10
	-15		+15		0	0		-20
	0		+70		5	5		-20
21	-16		+20	4	4	5	21	+35
	+8		-5		3	0		-10
	-10		+15		5	4		-35
22	-6		-16	17	1	0	22	-20
	-18		-16		2	0		-2
	-16		+5		0	0		-20
23	0		+20	14	0	0	23	-55
	+5		+5		0	0		0
	+20		0		0	5		+20
24	-20		+20	12	0	3	24	-10
	-10		-10		0	0		-30
	+10		+15		5	5		-5
25	+30		-40	9	10	15	25	-10
	0		0		0	0		-5
	0		-10		10	10		+30
26	+6		0	13	4	6	26	+10
	-8		+5		3	4		-20
	0		-10		0	0		+15
27	+10		0	7	5	5	27	+35
	+10		+10		0	0		-5
	-7		+5		7	10		-45
28	+50		+35	27	5	5	28	-20
	0		-5		5	6		-5
	+45		-45		10	10		+45
29	+35		+80	30	5	5	29	+15
	+5		±10		15	12		-15
	-85		+40		5	14		-25
30	+50		-55	23	5	6	30	+80
	+20		0		20	20		-10
	+25		+20		5	5		+40
31	+20		+10	20	0	0	31	-10
	+10		-20		10	8		+10
	-5		-20		5	6		+10

SPLICER Johnson TESTER Smith CALCULATOR Albert
SET NO. 8244 SET ZERO 0-0-0
TEST TO (A) Poles 124-125 DATE 10-21-27
TEST TO (B) " 192-193
REMARKS:

Group	Gauge	No. of Quads	Observed Resultants Ph. to Side Ave.	Ph. to Side Max.	Side to Side Ave.	Side to Side Max.
Green	19	31	4.7	15	4.6	20

Fig. 15.

PRINTED IN U.S.A. FORM E 988

CAPACITANCE UNBALANCE DATA SHEET

WITHIN - QUAD UNBALANCES

CABLE (A) Culver - (B) Dorchester LOADING SECTION 3

TEST POINT Poles 160-161

ESTIMATE NO. 2010 PRINT NO. 15 TYPE OF TEST Final

DIRECTION A Culver			QUAD NO.	DIRECTION B Dorchester			SPLICING INSTRUCTIONS						BUILT UP TO BE MET	RESULTANT - UNBALANCES					
PH. TO SIDE		SIDE TO SIDE		PH. TO SIDE		SIDE TO SIDE	QUAD A	PAIRS	WHITE	BLACK	QUAD B	*		CALCULATED			OBSERVED		
WHITE	BLACK			WHITE	BLACK									PH. TO SIDE WHITE	PH. TO SIDE BLACK	SIDE TO SIDE	PH. TO SIDE WHITE	PH. TO SIDE BLACK	SIDE TO SIDE
+15	-10	+10	1	-12	-5	-5	1	X	—	—	29			10	5	5	10	5	5
+16	+8	-35	2	-10	+5	-15	2	—	—	—	15			2	8	10	0	10	10
+10	-10	-6	3	-20	-15	-8	3	—	—	—	31			0	0	4	0	0	5
+26	-90	+20	4	+20	+15	-5	4	—	X	X	8			16	5	8	15	5	8
0	-10	-5	5	+55	+18	+10	5	X	X	—	19			0	4	5	0	0	5
+16	+6	-8	6	-15	-12	+10	6	—	—	X	1			4	1	3	5	0	3
-15	+6	-6	7	0	+5	+10	7	—	X	X	6			0	6	4	0	6	5
+40	-28	+10	8	+10	-85	-28	8	—	X	X	21			5	7	0	5	10	0
+20	+10	0	9	-40	-10	0	9	—	—	—	3			0	5	8	0	5	10
-6	-60	-8	10	+5	+70	+15	10	X	—	—	5			12	5	2	12	5	2
-5	-10	-16	11	+5	+6	+6	11	X	—	X	2			0	0	1	0	0	0
-8	+6	0	12	+20	+15	-10	12	—	—	X	11			3	0	6	3	0	5
-16	+20	-8	13	0	-10	+5	13	—	X	—	22			4	0	6	5	0	5
+30	0	-10	14	+20	0	+5	14	X	X	—	25			0	10	5	0	10	7
+20	+15	+20	15	-18	0	+25	15	X	X	X	26			5	5	0	5	5	2
+25	0	-10	16	-30	+5	-14	16	—	—	X	16			5	5	4	5	7	5
+40	-10	+20	17	-16	+5	-16	17	X	X	X	28			5	10	15	6	10	15
+35	-30	+7	18	-30	-40	+5	18	X	—	X	18			5	0	2	5	0	0
-10	0	+28	19	+6	0	-16	19	—	X	X	24			0	5	2	0	4	5
+75	0	-15	20	+10	-20	-20	20	[illegible]	X	X	10			5	5	0	5	5	0
-16	-10	+8	21	+35	-35	-10	21	—	—	—	4			4	5	3	5	4	0
-6	-16	-18	22	-20	-20	-2	22	X	—	X	17			1	0	2	0	0	0
0	+20	+5	23	-55	+20	0	23	X	—	X	14			0	0	0	0	5	0
-20	+10	-10	24	-10	-5	-30	24	—	—	X	12			0	5	0	3	5	0
+30	0	0	25	-10	+30	-5	25	—	—	—	9			10	10	0	15	10	0
+6	0	-8	26	+10	+15	-20	26	X	—	—	13			4	0	3	6	0	4
+10	-7	+10	27	+35	-45	-5	27	X	X	—	7			5	7	0	5	10	0
+50	+45	0	28	-20	+45	-5	28	X	—	X	27			5	10	5	5	10	6
+35	-85	+5	29	+15	-25	-15	29	X	X	—	30			5	5	15	5	14	12
+50	+25	+20	30	+80	+40	-10	30	—	—	X	23			5	5	20	6	5	20
+20	-5	+10	31	-10	+10	+10	31	X	—	—	20			0	5	10	0	6	8

SPLICER Johnson TESTER Smith CALCULATOR Albert

SET NO. 8249 SET ZERO 0-0-0

TEST TO (A) Poles 124-125 DATE 10-21-27

TEST TO (B) " 192-193

REMARKS:

GROUP	GAUGE	NO. OF QUADS	OBSERVED RESULTANTS PH. TO SIDE AVE.	PH. TO SIDE MAX.	SIDE TO SIDE AVE.	SIDE TO SIDE MAX.
Green	19	31	4.7	15	4.6	20

* These spaces used for checking purposes

Fig. 16.

10.02 The data spaces at the top and bottom are the same for both forms. At the top are spaces for recording the number of the loading section on which the testing is done; the location of the test point; the type of test, whether final or semi-final; the name of the cable route; the estimate number assigned to the work; and the number of the print (if this is used) showing the splicing procedure for the particular test point. At the bottom are spaces for recording such information as the average and maximum capacitance unbalances resulting from the work; the names of the testers and splicers involved in the work; etc. A space designated "calculator" is provided for those cases where someone other than the tester "dopes" the data sheets. The average of the resultant unbalances observed at final test splices should be computed for each gauge or segregated group and recorded, together with maximum resultant unbalances observed for the different groups, in the summary table at the bottom of the sheet. It is of course unnecessary to record average and maximum values for semi-final test splices since such values are not indicative of what the electrical condition of the loading sections will be on completion of the cable.

10.03 Considering form E-987, the main data space is divided by a vertical double line separation mark at the center of the form into two equal and identical portions, thus providing double form capacity. Considering the left portion only, the unbalances for quads in Direction A are recorded in the column "Unbalance" to the left of the "Splicing Diagram," and the quad numbers placed in the extreme left column. The unbalances and quad numbers for Direction B are placed in similar columns at the extreme right (to the left of the center line). In the blank space below "Direction A" and "Direction B" of the extreme right and left columns are recorded the names of the cable in accordance with directions chosen. Each space provided for recording the unbalances of a quad is divided into three parts. The phantom-to-white side unbalance is recorded in the upper part, the side-to-side unbalance in the middle, and the phantom-to-black side unbalance in the lower part. The quad in Direction B that is to be spliced to a given quad in Direction A is selected as previously described, and its number and unbalances entered in the two columns just to the right of "Splicing Diagram" and opposite the quad to which it is to be connected.

10.04 The "Splicing Diagram" column is provided to show the manner in which the quads should be connected together in order to reduce the capacitance unbalances. The four lines at each side represent the four wires of a quad, the upper two denoting the white side and the lower two the black side. This diagram should be completed in accordance with the combinations of Fig. 13 to show the manner in which the quads should be spliced. The resultant unbalances should be calculated and placed in the calculated resultant column horizontally opposite the corresponding primary readings of the Direction A quads. Under the observed resultant column, the unbalances measured in check tests may be entered. With the exception of built-up unbalances, the signs of calculated and measured resultants need not be recorded.

10.05 Form E-988 provides space for recording the same data as form E-987, but as will be noted, the arrangement is somewhat different. Each horizontal line provides space for entering all data for one quad in each direction of test, the spaces for the three unbalances being separately indicated under the two "Direction" columns and under the two "Resultant" columns. In place of splicing diagrams, the descriptive symbols "X" and "—" are used. These symbols are entered under the heading "Splicing Instructions" and in the spaces designated "Pairs," "White," and "Black" which are arranged in the same order as the three descriptive words given in Fig. 14.

10.06 It will be noted that the unbalances of the quads in Direction B are not transferred to other spaces at the time of "doping" the sheets as is done on form E-987. When a quad of Direction B is selected to go with quad 1 of Direction A, for example, its number is entered in the space, "Quad B" under the heading "Splicing Instructions" and in the same horizontal line with quad 1 of Direction A. The splicing instructions and calculated resultants must be determined by referring to the data under the two "Direction" columns.

10.07 An additional column, "Built-up—To be Met," is provided on Form E-988 for indicating unbalances that are built-up at one semi-final to meet high ones at the other semi-final, or high unbalances to neutralize which unbalances will be built-up at the other semi-final splice. The layout of Form E-987 does not permit similar columns but suitable check notations can be entered in the ample spaces of the various "Quad No." columns.

11. CABLE TROUBLES INDICATED BY SET READINGS

11.01 The presence of cable troubles such as crosses, opens, grounds, and leaks is usually made evident during measurements with the capacity unbalance set, which generally gives a fairly distinct indication of the nature of the trouble. By referring to Figs. 9 and 10 and assuming certain troubles to exist, it can in most cases be determined what effect the trouble will have on the various elements of the circuit and in turn the manner in which this effect will act on the unbalance condition shown by the formulas. The symptoms of various types of troubles are given in the following paragraphs, and in a few cases Figs. 9 and 10 are studied for the explanation.

11.02 It is desirable to clear troubles as soon as they are detected and before the testing work is resumed, but this procedure in many cases is evidently impracticable. Progress of the construction work, the number of men available for tests and splicing, and other things may have some bearing on the method followed. When troubles are detected at a semi-final splice and cannot be cleared at once, the quads involved may be connected through to quads having average unbalances, and the troubles cleared prior to beginning the final splice. At the time of clearing the troubles it is desirable to make a test splice at the trouble point on the quads affected. Any high unbalance remaining after this procedure can generally be reduced to satisfactory values at the final splice. When a trouble is detected at a final splice, it should, if practicable, be cleared before the splicing is begun because no later opportunities will be offered for obtaining further reduction. It should be noted that if high unbalances remain after the final splice is completed, these may be cared for by the application of the balancing pair.

Crosses Within Quads

11.03 A CROSS BETWEEN THE TWO WIRES OF A PAIR results in no tone in the side-to-side and the phantom to the crossed pair measurements. A correct reading will be obtained for the other phantom-to-side measurement.

11.04 From Fig. 10 it is seen that a cross between the two wires of a pair for the side-to-side arrangement short circuits either the oscillator or the receiver, and therefore that no tone will be heard in the side-to-side measurement. Fig. 9 shows that inasmuch as the black pair is normally short circuited during the phantom-to-white measurement, an additional short circuit across this pair will not affect the measurement. A cross between the wires of the white pair, however, short circuits the oscillator during the phantom-to-white pair test and no tone will be heard.

11.05 A CROSS BETWEEN TWO WIRES OF DIFFERENT PAIRS results in a very loud tone in any measurement.

11.06 A cross of this nature short circuits one of the bridge arms in any measurement and thus greatly upsets the balance.

11.07 A CROSS BETWEEN THREE WIRES results in no tone in the side-to-side and the phantom to the crossed pair measurements. A very loud tone will be heard in the other phantom-to-side measurement.

11.08 A CROSS BETWEEN ALL FOUR WIRES results in no tone in any measurement.

Cross with Wire External to Quad Tested

11.09 A cross between a wire of the quad under test and a wire of another quad results in a loud tone in the phantom to bad pair measurement. The other phantom-to-side unbalance will be incorrect but probably not indicative of trouble. The side-to-side reading will not generally be affected by the trouble.

11.10 If the cross is with the W wire, for example C_w (shown in dotted lines on Fig. 9) will be increased by the capacitance to ground of the external conductor; and as seen from the equation for phantom-to-white unbalance, this will add capacitance to the C_x arm and not a corresponding amount to the C_y arm, thus producing a condition of unbalance.

11.11 In the phantom-to-black side connections, the capacitance to ground of wires W and WM, which are shorter for this test, is increased because of the added capacitance to ground of the external wire with which wire W is crossed, but as seen from the formula the capacitance to ground of wires W and WM does not enter directly into the phantom-to-black side unbalance. Inasmuch, however, as the external wire is now connected to the same point of the bridge as wires W and WM, C_x and C_y will be increased by the value of the direct capacitance between wires B and BM and this external conductor, and unless this increase is equal for the two arms, an unlikely condition, an unbalance will of course be caused. For the side-to-side connections, the only result will be added capacitance to ground of the W wire, which does not appreciably affect the measured side-to-side unbalance.

11.12 The indications of all types of crosses given above assume a low resistance cross. If the resistance is high, the indications will not be so distinct and will more or less approach the ones given later for "Low Insulation."

Opens

11.13 The effect of an open decreases as the distance between the open and the testing end of the cable portion increases, it being readily seen that when the open falls very near to the distant end, the normal testing condition is practically obtained. The indications of trouble given in the following assume the opens to be sufficiently close to the testing point to cause an appreciable effect, and that all opens in a quad occur at the same point.

11.14 AN OPEN IN ONE WIRE results in large unbalance in the phantom to bad pair, and in incorrect readings for the other two measurements but readings probably not indicative of trouble.

11.15 Referring to Fig. 10 and assuming the open to be in the W wire: since the capacitance of a condenser depends partly upon the size of its plates and, therefore, in this case upon the length of the two wires forming the plates, a shortening of wire W will cause a reduction in both C_1 and C_2 and the reduction for obvious reasons will not be greatly different in the two cases. A reference to the side-to-side formula will show that an equal reduction in C_1 and C_2 does not affect the value of C_u, and hence that unless the difference in reduction of the two capacitances were quite appreciable the resultant unbalance would not be sufficiently higher than that in a good quad to give positive indication of trouble.

11.16 In the phantom-to-white arrangement, Fig. 9, the shortening of W lowers the values of C_1, C_2, and C_w, all three of which are noted as being effective in lowering C_x, but as having no similar effect on C_y. Hence, a large unbalance will occur. Considering the phantom-to-white condition again but assuming the open to be in the B wire, which is the same as studying the effect on the phantom-to-black unbalance by an open in W, it is readily seen that the reduction of C_x and C_y will be of the same order of magnitude and, therefore, that positive indication of trouble would not be given by an unbalance measurement.

11.17 OPEN IN BOTH WIRES OF A PAIR results in incorrect readings of the three unbalances but probably will not give indication of trouble.

11.18 OPEN IN ONE WIRE OF EACH PAIR causes loud tone to be heard in both phantom-to-side measurements, and a high side-to-side unbalance.

11.19 OPEN IN THREE WIRES causes high unbalance in measurement of the phantom to the pair having the good wire. The other two readings will be incorrect but not necessarily indicative of trouble.

11.20 OPEN IN ALL FOUR WIRES causes all readings to be incorrect, none of which will give positive indication of trouble.

Grounds

11.21 GROUND ON ONE WIRE results in high reading of phantom-to-grounded pair, and incorrect readings, but possibly no indication of trouble, in the other two measurements.

11.22 GROUND ON BOTH WIRES OF A PAIR results in no tone in the phantom-to-grounded pair and in the side-to-side measurement, and no positive indication of trouble in the other phantom-to-side measurement.

11.23 GROUND ON ONE WIRE OF EACH PAIR results in a very loud tone in all three measurements.

11.24 GROUND ON THREE WIRES results in no tone in the side-to-side and in the phantom to the pair having both wires grounded. A very loud tone will be heard in the other phantom-to-side measurement.

11.25 GROUND ON FOUR WIRES results in no tone in any measurement.

11.26 The reasons for the symptoms of trouble caused by grounds may be seen by referring to Figs. 9 and 10 and remembering that the effect of ground is the shorting out of certain condensers of the capacitance networks represented. It is assumed in the foregoing that the grounds are of low resistance. When such is not the condition, the indications of troubles will be more nearly like those of "Low Insulation."

Low Insulation

11.27 Inasmuch as the capacity unbalance set is not equipped to balance out insulation unbalances (leaks), when these occur it will be impossible completely to eliminate the tone heard in the receiver. Sharp null points cannot be obtained and the differential air condenser may be rotated some distance to either side of the estimated minimum point without producing an observable change in the tone heard.

Split Pairs

11.28 A split pair is formed by splicing the two wires of one pair in one direction from a test point to two wires of different pairs in the other direction. Fig. 17 shows one type of split pair, in which the white and white mate wires of a Direction A quad are spliced to the white and black wires of a Direction B quad. A trouble of this kind causes a very loud tone in the side-to-side measurement, and incorrect and probably high phantom-to-side measurements.

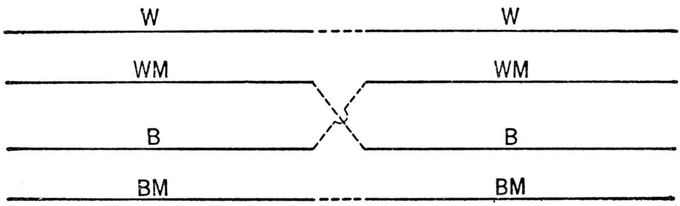


Fig. 17.

Split Quads

11.29 Figure 18 represents a form of split quad, caused by the interchanging of one wire between two quads. In this case a loud tone will be heard in the measurement of the phantom to the pair having the interchanged wire. The other two unbalances may or may not be high. It should be notec that two quads are involved and the measurements on the two will give similar indications of trouble.

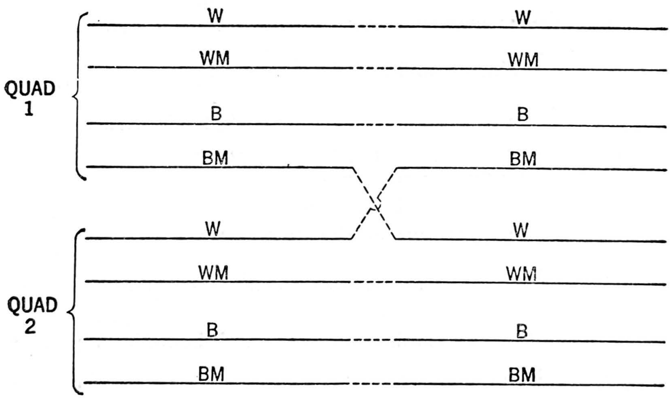


Fig. 18.

11.30 A split quad may also be caused by interchanging the two wires of a pair. This would be the case in Fig. 18 if wire "B" of quad 1 and wire WM of quad 2 were also interchanged. This type of split quad is uncertain of detection by capacitance tests.